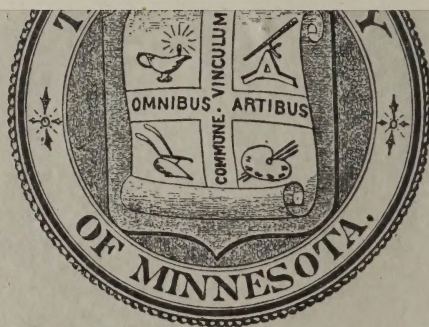


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Topographic and Geologic Survey of Pennsylvania.

RICHARD H. HICE, State Geologist.

Geologic Map of Southwestern Pennsylvania.

REPORT NO. 2.

HARRISBURG, PA.
WM. STANLEY RAY, STATE PRINTER
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- Plate IX. Geologic section through Claysville, Amity, Brownsville and Connellsville quadrangles.
- Plate X. Geologic section through Rogersville, Waynesburg, Mason-town and Uniontown quadrangles.



THE GEOGRAPHIC BASE.

The area embraced in this map covers forty-eight 15' quadrangles in the southwest portion of the State, together with portions of nine quadrangles along the western boundary of the State (a strip about one mile in width) and a strip along the southern boundary of the State, embracing portions of eight quadrangles which lie for the most part in West Virginia and Maryland. The total area embraced in the map is 11,227 square miles, being 24.9 per cent. of the total area of the State. Of the forty-eight quadrangles entirely embraced in the map all but ten have been mapped topographically, those remaining unmapped being the Penfield, Reynoldsville, Brookville, Wilpen, Windber, Stahlstown, Hyndman, Berlin, Meyersdale and Confluence. The narrow strips of the quadrangles along the western and southern boundaries of the State have all been mapped topographically.

The geographic base used is far more accurate than any map of a large portion of the State heretofore issued. In the preparation of this map the topographic sheets of the quadrangles which have been mapped were carefully reduced, and the portions of the map thus covered are far within the possible accuracy of a map on this scale. This reduction was from the scale of 1-62,500 of Nature, approximately 1 mile to the inch, to a scale of 1-500,000 of Nature, or 8 miles to the inch.

In addition to the detailed topographic work there was available a large mass of data of great accuracy. Surrounding the published topographic sheets there is in all cases a strip of accurately mapped territory embracing portions of the unpublished areas. Over all the area embraced in the map work has been done towards the final completion of the topographic map. This consists of what is known as "Primary control," which is the accurate location, far within the possibilities of the map to depict, of a number of prominent points which can be used for reference in the preparation of the detailed map of the region. All these accurately located points

were carefully assembled in the work of the preparation of the map, and the data available from other sources was adjusted to these locations. The result of all this work was a map in which the accurate location of all points, streams and boundaries, falls well within the possibilities of the scale to show.

The map was constructed by the United States Geological Survey as a portion of the millionth map of the world. It was constructed on a scale of 1-500,000, and for use in State work was enlarged to 1-250,000, approximately 4 miles per inch.

THE GEOLOGIC MAP.

In the preparation of the geologic map all known sources of information were used. A number of the quadrangles which have been mapped topographically, have also been mapped geologically under the co-operative agreement between the United States Geological Survey and the State Geological Survey. The reports of the Second Geological Survey of Pennsylvania have been freely drawn upon, and other sources of information utilized as fully as possible.

Where the various quadrangles have been mapped geologically, the work has been published on the scale of 1-62,500 of Nature, approximately 1 mile to the inch. In reducing these maps to a scale of one-fourth the published size it is obviously impossible to retain the details and all the individual formations depicted on the large scale map. These, therefore, have been in some cases combined.

The reports of the Second Geological Survey of Pennsylvania are filled with detailed geologic sections. Where the areas have been mapped topographically it was possible in most cases to accurately locate many of these sections and therefore to show well within the scale of the map the position of the formations given in the detailed sections.

Where topographic maps were not available the geology as indicated in the reports of the Second Geological Survey, with such changes as it has been possible to secure from later sources, has been adjusted to the new and better base of the present map.

It will be thus seen that geologically the map is of three degrees of accuracy. (A) Over much of the area the extent of the formations as shown is far within the scale of the map. (B) Over another portion of the map, where the topographic maps were available, the geology is also believed to be well within the possibilities of the map. (C) A third portion of the map, mainly in the southeastern area, possesses less accuracy, but owing to the better geographic base and the recent geologic work along the Maryland line, it is believed the formations are more accurately shown than in any preceding map.

THE GEOLOGIC SECTION.

No attempt is made to indicate on the map the unconsolidated rocks on the surface, which belong to the Pleistocene, or last geologic age. These unconsolidated materials consist of glacial debris, and of the materials of decay from consolidated rocks, which either remain in place or have been moved by running water into the streams, and are now found as alluvial benches or terraces along many of them. A portion of the material of glacial origin has also been washed down from the more northerly latitudes, and has been spread along the streams in terraces, or is found in a thin layer of outwash upon the underlying consolidated rocks. While these formations are of great interest geologically, and also from an economic standpoint, it was not thought best to show them on this map.

The consolidated rocks over most of the area shown belong to the Carboniferous age, although the southeastern portion of the area mapped embraces rocks of older age, down to the time of the Trenton limestone. The principal divisions of the rocks found in the area mapped, with their recognized geological age, is shown by the following table:

ROCKS OF SOUTHWESTERN PENNSYLVANIA.

Carboniferous—

Permian, or Dunkard Series. ("Upper Barren Measures.")

Greene formation.

Washington formation.

Pennsylvania Series. ("Coal Measures" Groups).

Monongahela formation, "Upper Productive Measures."

Conemaugh formation, "Lower Barren Measures."

Allegheny formation, "Lower Productive Measures."

Pottsville formation.

Mississippian Series, or "Lower Carboniferous."

Mauch Chunk formation.

Burgoon (Logan, "Big Injun") sandstone.

Cuyahoga shale, (limestone, and sandstone)

Berea (Corry) sandstone.

Catskill—Erie—

Knapp formation.

Conewago formation.

Devonian—

Chemung formation.

Portage formation.

Genessee shale.

Hamilton and Marcellus formations.

Oriskany sandstone.

Helderberg limestone.

Silurian—

Waterlime group.

Salina group.

Niagara group.

Medina group.

Ordovician (Lower Silurian)—

Hudson River shales (Lorraine).

Utica shales.

Trenton limestone.

CARBONIFEROUS SYSTEM.

PERMIAN, OR DUNKARD SERIES.

The youngest consolidated rocks in the area covered by the map are the upper portion of the Carboniferous,* the Permian, or Dunkard Series, as named by Dr. I. C. White in 1891, from their exposures along Dunkard creek in Greene county. In the earlier reports of the Second Geological Survey and in the

*The only known exception to this statement is a small igneous dike (peridotite) in Fayette and Greene counties. See Top. and Geol. Surv. Com. Rept. 1910-1912, p. 150.

reports of the First Geological Survey, these beds were known as the "Upper Barren Measures," as it was believed at the time they were thus named they did not possess coals of workable thickness.

These rocks embrace that portion of the Carboniferous system lying above the top of the Waynesburg coal. They are largely confined to Greene and Washington counties, although small patches still remain in Fayette, Westmoreland and Allegheny counties. The general dip of the rocks in this region is towards the southwest, so that the greatest thickness in this State is near the southwest corner of Greene county.

The Dunkard series has been divided into two formations, the Greene, extending from the highest of the known rocks to the top of the Upper Washington limestone, and the Washington formation, embracing the rocks from the top of the Waynesburg coal to the top of the Washington limestone. The total thickness of both formations in this State is about 1,200 feet, and how much has been eroded we have no means of knowing.

PENNSYLVANIAN SERIES.

Monongahela Formation.

This formation in early reports on the geology of the State and in some of the reports of the Second Geological Survey, was called the "Upper Productive Measures." It extends from the top of the Waynesburg coal down to the bottom of the Pittsburgh coal. This formation underlies the wide expanse of the Permian Series in the southwestern portion of the State and outcrops beyond it to the north and east, occupying a considerable portion of Allegheny, Fayette and Westmoreland counties. There are small areas also found in Beaver, Indiana and Somerset counties, and five small remnants have escaped erosion in the Broad Top coal field of Huntingdon, Bedford and Fulton counties. The thickness of the formation in Pennsylvania varies from about 350 feet to 400 feet.

This formation is of value, economically, from the fact that it embraces the Pittsburgh coal bed, which is almost uniformly of workable thickness and purity wherever found in Pennsyl-

vania. This bed produces approximately 60 per cent. of the bituminous coal mined in the State. Other coals in the Monongahela formation are locally of workable thickness.

Conemaugh Formation.

Immediately underlying the Monongahela formation occurs a series of rocks, 500 feet to 700 feet in thickness, which the early geologists of Pennsylvania termed the "Lower Barren Measures," from the fact that they were supposed to contain no coals of value. This series, which extends from the top of the Upper Freeport coal to the base of the Pittsburgh coal, is now known as the Conemaugh formation, from the stream of that name.

The Conemaugh formation occupies a very large portion of the area embraced in the map, including portions of Washington, Beaver, Allegheny, Butler, Armstrong, Indiana, Westmoreland, Fayette and Somerset counties, indeed being found in all the counties embraced in the map, with the exception of Greene on the southwest and Bedford on the southeast.

Allegheny Formation.

This series of rocks, extending from the top of the Pottsville sandstone to the top of the Upper Freeport coal, or the base of the Mahoning sandstone, was known to the early geologists of the State as the "Lower Productive Measures." It is to be distinguished from the underlying Pottsville by the greater prevalence of workable coals and the smaller amount of sandstone contained. It can be distinguished from the overlying Conemaugh formation by the presence of several workable coals, the best known and defined being, in ascending order, the Brookville, Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport, and Upper Freeport.

In the area covered by the map the Allegheny formation bounds the Conemaugh to the north, and extends far down the valleys into the overlying formations. It is also found

in irregular extension to the West Virginia line through the counties of Fayette and Westmoreland, where it is brought to light by the acute folding of that region.

The coals of the Allegheny formation furnish about 40 per cent. of the bituminous output of Pennsylvania.

Pottsville Formation.

Underlying the Allegheny formation occurs the great Pottsville sandstone. It is not very prominent in the area covered by the map.

In the northern portion of the map the Pottsville is found in the valleys of the larger streams, occupying portions of the Beaver, and middle parts of the Allegheny valleys. In western Pennsylvania the Pottsville consists of three members, the Homewood sandstone at the top, the Mercer coal group, and the Conoquenessing sandstones. The economic importance of the Pottsville in this area is quite small, aside from the flint clays of the Mercer horizon, which are the most valuable flint clays in the State.

MISSISSIPPIAN SERIES.

Except in the southeastern portion of the area covered by the map, where they are brought to light by the folding which has there taken place, the rocks underlying the Pottsville are only found in a portion of the immediate Allegheny and Clarion valleys. These rocks lie unconformably beneath the Pottsville in southwestern Pennsylvania. This nonconformity extends throughout the region covered by the map. The Mauch Chunk red shale, with the Greenbrier limestone, has a thickness of about 200 feet in the southwest corner of the State, separating the Conoquenessing and Burgoon sandstones. This thins going north and east until, in the vicinity of Pittsburgh, the Conoquenessing and Burgoon are in contact.

The rocks underlying the Pottsville are of great economic importance in the area covered by the map, as they include many of the more important oil bearing sands. The Berea sandstone is regarded as the base of the Mississippian Series.

DEVONIAN SYSTEM.

The rocks underlying the Mississippian Series are only known over most of the area covered by the map by well records. These same rocks, however, are shown in a general way in the southeastern portion of the area covered by the map, where they have been thrown up by the folding.

Any discussion of these rocks throughout southwestern Pennsylvania entails a study of well records, and is not in place in describing a general geologic map, which only shows the rocks exposed at the surface.

STRUCTURE.

From an economic point of view the determination and delineation of structure is of the highest importance, and in the geologic work done in co-operation between the United States Geological Survey and the State Survey particular attention has been given to this phase of the study.

In the report of the Commission in 1906-08, Dr. G. H. Ashley explained the meaning of the word structure, and the method of representing it in the folio publications. From his report the following description is taken:

“General Statement. In the recent geologic work in which the Federal and State governments have co-operated the determination and delineation of structure has been considered as of the highest importance, and a large share of the work and its cost has been devoted to that side of the study. As work in this direction is a distinct advance over the work of the earlier surveys, and as men without engineering training are not familiar with the meaning of the word as here used, or the method of representing the structure in recent publications, the subject is here treated at some length and from a very elementary standpoint. There are four phases of the subject to be explained: (1) The meaning of the word ‘structure’ as here used; (2) the method of its graphic representation; (3) the methods of its determination in the field; and (4) the degree of accuracy and reliability of the structure as presented.

•

"If it were possible to remove all of the rocks lying above the top of any selected rock layer in western Pennsylvania, such as the Pittsburgh coal, it would be found that the top of the layer formed a surface like that of a gently rolling country consisting, in the main, of low, rounded ridges or swells between equally gently rounded valleys. The ridges and valley would be found in western Pennsylvania to have a general trend of northeast and southwest. Some of the ridges and valleys would be found to be very long, extending sometimes half way across the State, but in all cases the ridges would nose out and the valleys run out as two nearly parallel ridges run together and coalesce. This would be true only of the western part of the State west of a line which is followed by the east side of Cambria county. For a short distance west of this line the ridges and valleys would usually be quite long and narrow and regular. Further west they would usually be shorter, broader, and less regular, until along the western edge of the State this rock surface which we have assumed to have been exposed would appear to be a gently sloping surface, sometimes rising into oval or sugar-loaf mounds and similar depressions, but in general sloping toward a line drawn from Pittsburgh southwestward toward Huntington, West Virginia. Further examination would show that this line was the axis of a major valley or basin, but that in going eastward from this line, the ridges and valleys occurred at higher and higher elevations. By structure here is meant the 'lay' of any bed, or the shape of one of its bounding surfaces, as just described.

"The geologist recognizes that in the main these ridges and valleys are folds produced by pressure from the southeast, as a bolt of cloth partly extended on a counter and pushed upon from one end will be thrown into many transverse folds or wrinkles. To the up folds or ridges the geologist gives the name 'anticlines,' to the down folds or valleys, the name of 'synclines;' the direction of slope at any point is the 'dip,' and a horizontal line at right angles to the dip along the bed is the 'strike.'

"*Method of Graphic Representation.* In attempting to represent the structure, three methods are used. One method is

by hachure lines, or some modification of them; that is, on the map of the area involved, short lines are drawn in the direction of the dip. Usually the part of the line down the dip is made heavier than the opposite end. In this way it is possible to show the direction of the dip, the position of the anticlines and synclines, and, if the length of the line is varied as the dip varies, it may be possible to suggest whether the dip is high or low. In this method there is only one definite thing shown—the horizontal position of the axes of the anticlines and the synclines. All the rest is indefinite, and the method has, therefore, a very limited application from an engineering and practical standpoint. The second method consists in assuming that the rocks have been cut by a vertical plane and a drawing is made which represents the cut edges of the rocks where they are intersected by this plane. Just along the line of its intersection this method represents the structure with entire definiteness and with as great accuracy as the facts observed or obtained will allow. It shows not only the horizontal position of the axes and folds at the points of intersection, but their vertical position as well, expressed, it may be, in feet above sea level, and the exact slope of the rocks between the various axes of the anticlines and synclines, so that the exact position, vertically and horizontally, of any rock being studied may be determined. This is the most vivid way of representing structure. It has this great disadvantage, however—it shows the structure only along the line of the section. If the anticlines and synclines are long and regular such sections a mile apart may give a very fair idea of the structure. If the structure be irregular the sections must be correspondingly more numerous and near together. It is evident at once that, while such sections may give accurate information of the structure along the lines of the sections and general information of the region in general, if it be desired to get exact information as to the dip or elevation of any coal or other rock bed or any point off from one of the lines of section, it can only be done with difficulty, and at best, approximately.

“The third method is by use of contour lines. This method, while not so readily understood, or so graphic in its portrayal of the folding as the preceding method, has the great

advantage that it may be placed on a map with other features, and from the lines as drawn it is possible to determine at any point on the map the dip, strike and elevation of the rock surface that has been contoured. To understand the meaning of contours, let it be imagined, as before, that all of the rocks above the top or bottom of a selected layer be removed and that then the sea rises until just above the top of the highest fold, say, to an even number of 100 feet above its old level. Suppose now that it sinks 100 feet so that the top of the ridge project slightly above its surface. If it remains at this level a short time it might be assumed to make a slight beach mark where the waters meet the ridge. Such a beach mark might consist of a slight wave cutting in the rock or only of an inconspicuous ridge of seaweed, sand, etc., such as is ordinarily thrown up at high water on any beach to-day. Suppose the sea then sinks another 100 feet and remains until another beach mark has been made. Evidently the two beach marks will show the exact shape of the hill at the elevations above the old sea level at which the sea stood still. Where the slope from the first mark to the second was gentle the marks will be far apart. Where the slope was steep the marks will be near together. Assume then that the sea continued to sink, stopping at each even 100 feet long enough to make a beach mark, until it had returned to its old level; that a map of these beach marks had then been drawn and each marked with the elevations at which it was made. Such a line, when drawn on a map, is called a contour line. It is evidently a line of equal elevation, in this case, above sea level, and a map showing the structure by contour lines is called a structure contour map. The elevation of any point on one of the contour lines is, of course, shown by the designation of that contour line, but it is also evident that if the slope between any two adjacent contour lines be, or be assumed to be, even, the elevation of any intermediate point can at once be determined with close approximation. Thus, if a particular point on a map comes half way between 1,200 and 1,300-foot contours, its elevations may be assumed to be very close to 1,250 feet. If it be one-fourth the distance from the 1,200-foot to the 1,300-foot contour, its elevation is close to 1,225 feet, and so on.

"So that if a map be made showing by 20-foot contours the structure of the surface at the bottom of the Pittsburgh coal, an engineer, by turning to such map, can see at a glance the elevation above sea level of the Pittsburgh coal to within 20 feet, and usually within 5 feet, either at the point at which he is standing or at any other point on the map about which he is interested, even though the coal at that point be hundreds of feet under ground. If, further, the map shows by contours the elevation of the surface of the land at that point, by subtracting the one from the other, he may obtain the depth below the surface of the bottom of the coal and will know at once how far he must drill or sink the shaft in order to reach the coal.

"Methods of Determining Structure. In determining the structure, two general methods have been used. The first method is, briefly, to plot on the map all of the elevations of the selected surface it is possible to obtain, and then to connect them with lines of equal elevation. Thus, suppose that a map is being made in the Pittsburgh coal field and the bottom of the Pittsburgh coal has been selected as the surface to be contoured. If there be any mines on that coal in the area, copies of the elevation of the coal would be made from the mine maps of the companies. These would then be reduced by photography to the scale of the field map and the elevations transferred to the field map. Then there would be added to the map the elevations of the bottom of the coal at every point where it could be found in outcrop, as at small mines or 'country banks,' prospects or exposures in road, railroad or steam cuttings, or when seen as black smut marks across the roads. If any drilling has been done to prove the coal, or if there are oil or gas wells in the area which pierce the coal and the records of which give the depth of the coal, the elevations so obtained are added. When necessary, the elevations of the tops of the wells are determined in the field. Then having determined the elevation at the surface of other coals, limestones, sandstones or other rocks that outcrop, and knowing, or finding from a study of the stratigraphy, the distance from the Pittsburgh coal up or down to the outcropping bed by adding or subtracting, as necessary, a great number of addi-

tional elevations on the coal may be obtained, until finally the field sheet of a single quadrangle may contain many hundreds of elevations on a single horizon. Then lines are drawn between points of equal elevation, the lines passing through or to one side or the other of any elevation as the elevation is just at, above, or below the elevation of the line being drawn.

"In this case, the reliability and accuracy of the final result will depend upon two things: The abundance and uniform distribution of the elevations and the accuracy with which the individual elevations are determined. In the field the elevations are determined by the barometer, by the hand level or by the spirit level, or stadia. In all cases the measurements are checked on or measured from bench levels instrumentally determined in the making of the topographic map. Experience has shown that where frequently checked on bench marks, as in western Pennsylvania, barometric determinations will be correct within 50 feet, though the limit of error is hardly less than that. With the hand level the limit of error should not be more than 5 or 10 feet, while with the spirit level, or stadia, the limit of error should be well within 5 feet, and generally within 1 foot. The liability of being mistaken in the identification of the bed itself or of some other bed from which its elevation may be computed, is a constant possible source of error, as is also the constant possibility that the interval from an outcropping rock to the surface to be contoured may have changed from what it is at the nearest point at which this interval could be measured. This method, using in the main the spirit level, has been applied in the Burgetts-town, Claysville, Carnegie, Sewickley and Clarion quadrangles.

"In the second method, vertical cross sections are drawn to scale so as to make a complete network all over the quadrangle. Ideally, every square mile should be crossed by one or more of these cross sections. These cross sections are drawn so as to follow in a general way routes taken in the field study of the geology, such as the roads, railroads, streams, hill slopes, etc. In making the field study of the geology, the geologist draws in his note book a large scale profile of the ground as he passes over it, and on this he represents graphically and with abundant notes every particle of geological data he can obtain

along the line he is traveling, not only actual exposures of the rocks, coals, mines, wells, etc., but everything about the soil or debris which may contain any clue to the character of the rock below. All of these data are placed on his profile at the proper elevation as determined by the barometer, hand level or spirit level. In the office the data are transferred from the field note book to the carefully drawn cross sections, the elevations being carefully corrected for any errors in the barometric readings where such can be detected. If the surface data are at all clear, it is usually then not difficult to draw what corresponds to the intersection of the plane with the horizon which it is desired to contour. The cross section paper used has horizontal lines, or they may be drawn to represent the vertical intervals at which contours are to be drawn on the map. Where these horizontal lines cross the line representing the position of the bottom of the Pittsburgh coal on the cross section, if that be the surface being contoured, or when the corresponding contour lines are going to cross the line of the cross section on the map, these points of intersection are drawn on the map and then connected together to form the contour map. In this method use is made of the levels from mine maps, drillings, etc., but all of the other data is taken into account as well. With a similar mode of obtaining elevations this method is much more accurate than the preceding. This is particularly true in the regions in which the outcropping rocks are mainly or entirely of Allegheny or Lower Conemaugh age, as in most of the Barnesboro, Patton, Punxsutawney, Curwensville and Houtzdale quadrangles, and large areas in some of the other quadrangles, where there is an entire lack of any rock that would serve as a key rock and where, in fact, the stratigraphic position of none of the coals, limestones, shales or sandstones can be determined by an examination of the rock stratum itself. Under these conditions, with the second method it is possible to carry the structure over larger areas within which it is not possible to recognize the stratigraphic position of any outcropping rock. In a region in which such rocks are the outcropping rocks, and where almost none of the outcrops are in unweathered exposures, even the second method may yield only uncertain results. Over

large areas in the quadrangles mentioned in the preceding paragraph just such conditions exist. Generally the presence of the sandstones has to be assumed from the scattering sandstone fragments on the surface. Often, where the land is all under cultivation the existence of stone fences or of small stone piles in the fence corners has been the best evidence obtainable of the presence and position of a sandstone. In certain places some sandstone has been locally more resistant than those above or below it, and its top can be traced around the hill slope by following the top of the scattered boulders that have been derived from it by weathering. In the rocks of the lower Conemaugh, it will be noted that the distance from the top of what appears to be the same sandstone in adjacent sections down to the Upper Freeport coal varies so greatly that even though the top of such sandstone be traced for several miles it is not sure how closely the underlying surface to be contoured will follow the same levels. Some of the difficulties of working out the structure are thus practically stated so that too much confidence may not be placed in the structure as shown. In general, the contour interval has been so chosen that the limit of error will not be greater than the contour interval. It is true that in many of the quadrangles over considerable areas the limit of error is well within the contour interval, but again, on the same quadrangles there may be areas in which the limit of error is much greater. In the latter cases it is usually planned to make the contour lines broken or dotted.

"The Structure as Represented. On the map, is brought together the structure, represented by contours, over a large part of southwestern Pennsylvania.

"Probably never before has the detailed structure of so large an area been accurately represented, certainly not in this country. It therefore represents an opportunity for the study of the folding of the earth's surface under the conditions here existing that it is hoped may be taken advantage of in the future.

"In drawing the structure of the large map, the Pittsburgh coal was chosen as the horizon to be contoured rather than one of the lower and more widespread horizons, because a lower

horizon would go below sea level in the southwest corner of the State—a condition that when represented is always apt to be misleading. In preparing the map the structure maps as published or prepared were reduced to the scale of the new map and the structure transferred. In several of the quadrangles the structure as originally drawn on the maps was on the base of the Pittsburgh bed. In these cases the structure was transferred without change. In other quadrangles various horizons have been used to contour on. The Washington limestone, Ames limestone, the Upper Freeport coal, the Middle Kittanning coal, the Lower Kittanning coal, have all been used. In these cases the distance was computed from the Pittsburgh coal up or down to the layer actually contoured on in any case. Usually the figures were taken in round numbers, as 300 feet below the Pittsburgh coal to the Ames limestone; 600 feet from the Pittsburgh coal to the Upper Freeport coal, increasing to 750 feet at the east. To the Lower Freeport coal 50 feet additional were added, and to the Lower Kittanning 200 feet additional. By knowing the intervals from one coal to another in any of the quadrangles and the assumed interval from the Pittsburgh bed to one of the coals in each quadrangle, the approximate elevation of any coal in the area may be computed from the map.

“The following table will therefore enable anyone to compute the actual elevation of the stratum in each quadrangle that has been used to contour on, and by using the intervals as given in the table of coals or the local descriptions, the approximate elevation of any other coal or stratum may be computed:

“TABLE GIVING STRATUM UPON WHICH CONTOURS HAVE BEEN DRAWN IN THE FIELD NOTES OR DETAILED PUBLICATIONS, AND THE ASSUMED DISTANCE FROM THE PITTSBURGH COAL TO THAT STRATUM.

	Feet.
Newcastle quadrangle, Middle Kittanning, ...	—700
Beaver quadrangle, Upper Freeport coal, ...	—550
(Ames limestone), ...	—260
Sewickley quadrangle, Ames limestone, ...	—260
Burgettstown quadrangle, Pittsburgh coal, ...	0
Carnegie quadrangle, Pittsburgh coal, ...	0

Claysville quadrangle, Upper Washington limestone, ...	+570
Amity quadrangle, Pittsburg coal, ...	0
Brownsville and Connellsville quadrangles, Pittsburgh coal, ...	0
Rogersville quadrangle, Pittsburgh coal, ...	0
Waynesburg quadrangle, Pittsburgh coal, ...	0
Masontown-Uniontown quadrangles, Pittsburgh coal, ...	0
Clarion quadrangle, Lower Kittanning coal, ...	-800
Kittanning and Rural Valley quadrangles, Vanport limestone, ...	-850
Elders Ridge quadrangle, Upper Freeport coal, ...	-700
Latrobe quadrangle, Pittsburgh coal, ...	0
Indiana quadrangle, Upper Freeport coal, ...	-700
Punxsutawney quadrangle, Upper Freeport coal, ...	-700
Curwensville and Houtzdale quadrangles, Lower Freeport coal, ...	-750
Barnesboro- Patton quadrangles, Lower Freeport coal, ...	-750
Johnstown quadrangle, Lower Kittanning coal, ...	-850
Ebensburg quadrangle, Upper Freeport coal, ...	-750

"In the above table the minus sign indicates that the amount given should be subtracted from the elevations given on the contour map; the plus sign indicates that the amount should be added.

"Without discussing the structural details, certain general features are readily apparent and need only be referred to.

"*First*, there is the general northeast-southeast trend of the folds. While not nearly so straight as they have frequently been represented, nevertheless, taking large distances, the folds in this part of the State tend to have axes running about N. 30° E. On the south line of the State the trend is more nearly north, running from N. 20° E. to N. 25° E. Toward the northern part of the map there is marked bending to the eastward. Had the map therefore been continued farther to the north and east, the general trend would have been more to the east, possibly as high as N. 45° E.

"In the *second* place there is noted a marked change from the closely folded anticlines and synclines of the southeast to the open gentle folds of the northwest, until to the northwest of Pittsburgh the structure is little more than an irregular, very gentle slope in which some parts project very slightly beyond adjacent parts. So gentle is much of the structure at the northwest that, except for the spirit-leveled elevations to which it was everywhere referred, it would hardly have been

possible to have detected any variations at all from a uniform slope, and the structure might have been drawn in with a ruler; and yet the work in oil and gas has shown that in many cases even these slight irregularities in the slope seem to have had a marked effect on the position of the oil and gas pools.

"In the *third* place it will be noted that the folds are, as it were, but wrinkles on the surface of a broad syncline, of which the axis runs southwest and northeast through Pittsburgh. South of Pittsburgh this axis coincides with the axis on the Ninevah syncline and farther north with the axis of the Fairmount syncline. Thus at the southeast the position of the Pittsburgh coal is theoretically on the Dulany anticline, 4,200 feet above sea level; on the Fayette anticline 1,800 feet above sea level; on the Belle Vernon anticline 1,050 feet above sea level; on the Amity anticline, the same, and in the Ninevah syncline it gets down to less than 100 feet above sea level. This is possibly even better brought out by a line through Indiana. Thus starting 10,000 feet above sea level in the southeast corner of the Ebensburg quadrangle, the Pittsburgh coal even in the Pavia syncline does not get below 4,200 feet above sea level; in the deep Wilmore basin to the northwest it gets down to 1,700 feet; west of that it keeps above this elevation until the Laurel Hill axis is crossed where it has a maximum elevation of 3,900 feet above tide, though to only 2,800 feet in the line being followed. From the Laurel Hill anticline to Indiana the synclines carry the coal below 2,000 feet, and the anticlines raise it above 2,500 feet. The Latrobe syncline carries the coal down to 1,700 feet at Indiana and still lower farther south. The Elders Ridge syncline carries it down to 1,500 feet and down to 1,100 feet farther south. The Greenville anticline can only raise it to 1,600 feet in the line here followed, though nearly 2,300 feet farther north, while in the Fairmount syncline the Pittsburgh coal south of Kittanning is only 1,550 feet above tide.

"In the *fourth* place it is to be noted that in the center of the major synclinal axis there is a general rise of the structure in the direction of the axes of folding to the northeast. Thus in the axis of the major syncline it will be noted that in the southwest corner of the State the Pittsburgh coal is almost

down to sea level—locally within 100 feet of it. Going toward Pittsburgh the strata in the center of the basin rise as in climbing toward the point of a spoon until at Pittsburgh the coal of that name is 1,000 feet above sea level. Going north-eastward the same rise continues until in the Clarion quadrangle in the lower part of the major basin, the Pittsburgh coal is theoretically over 2,000 feet above sea level. If the Uniontown syncline be followed it will be found near Uniontown to bring the Pittsburgh coal down to 550 feet above tide. At Latrobe the coal is not below 700 feet; at Blairsville about 1,000 feet, at Indiana it is 1,700 feet above tide. This tendency to rise to the northeast does not continue southeast of the Chestnut Ridge, and in many parts of that area may be reversed. Thus in the Uniontown quadrangle the position of the Pittsburgh coal on Chestnut Ridge is about 4,000 feet; east of Latrobe less than 3,500 feet; east of Indiana only 2,500 feet, and but little higher east of Punxsutawney.

“In the first syncline east of Chestnut Ridge the Pittsburgh coal is theoretically above 2,100 feet on the Uniontown sheet. East of Indiana it is down to 1,900 feet, but on the Curwensville sheet it ranges between 2,000 and 2,350 feet, so that the theoretical strike follows the axis of the folds. The Laurel Hill anticline east of the west wedge of the Johnstown quadrangle has raised the Pittsburgh coal theoretically to 3,900 feet; in the northern part of the quadrangle it is down to 2,800 feet and at Coalport to 2,400 feet; eastward on the Houtzdale quadrangle it raises to 2,900 feet again. In the Johnstown syncline, and in the Bradley, Mud Lick and Houtzdale synclines the coal keeps not far from 2,000 feet.

“*Fifth*, it emphasizes as has never been done before the undulating character of the folds in the direction of the axes. No such even-crested anticlines or even-bottomed troughs or synclines as have usually been pictured have been found to exist in the area covered by the map. Instead the synclines appear to be a series of elongated or oval or spoon-shaped basins separated by relatively high divides or buckles; and the anticlines consist of elongated or oval domes or crests separated by low ‘sags’ as they may be called. A study of the relative position of these basins and crests brings out some interesting

points. In the Uniontown-Connellsville quadrangles the basins and crests are set in alternate arrangement, while in Cambria county they are opposite. Thus, for example, the Uniontown basin is not opposite the highest part of the crests of the adjoining anticlines, but opposite the sags of those anticlines, and *vice versa*. In Cambria county, on the other hand, it will be noted that the highest part of the Ebensburg anticline is almost exactly between the lowest parts of the Wilmore and Johnstown basins adjoining it on either side. This is even more strikingly shown in the Latrobe quadrangle where domes in Fayette and Chestnut ridges and basins in the Greensburg and Latrobe synclines all fall in a line nearly normal to the strike. The same thing is true in the Roaring Run anticline, Elders Ridge syncline and Jacksonville anticline. On the whole the opposite arrangement appears to be more common than the alternative, though not enough so as to be made the basis of a theory in the matter. In the case of the Latrobe quadrangle a line lying nearly normal to the structure through the points of maximum folding south and west of Latrobe, from the southeast corner of the quadrangle to the Greensburg syncline, would cross contour lines to the extent of 5,400 feet; one through the maximum folding south of Blairsville would cross 5,150 feet, while through the nodes between, a line would cross only 4,150 feet. Other cases are even more striking. A nearly east and west line a little north of Johnstown in crossing from the Wilmore syncline to the Laurel Hill anticline, would climb up 2,950 feet and down 750 feet or a total of 3,700. A parallel line through Ebensburg would climb up 900 feet and down not at all, making a total of 900 feet.

"Unfortunately the areas not yet mapped prevent carrying this study out broadly. It should be noted, however, that in the cases cited that the lines passing over the greater amounts of ascent and descent in the structure are not proportionately longer than the other lines. The difference is made up in the difference in the steepness of the structural slope. Now it is a well known fact that a highly convex arch is longer than a lower arch of the same span. It would therefore appear that along certain lines transverse to the folding any selected rock stratum as folded is longer across the areas of maximum fold-

ing than the same rock is along other selected lines or what might be called nodal lines as they pass through the nodes of these undulating axes. This difference is probably not large. Calculation of the length of the Upper Freeport coal over the Chestnut Ridge anticline on a line southeast from Punxsutawney, as compared to the cord of the same arch, showed a difference of less than 5 feet, notwithstanding the rise of the arch at the center is 750 feet above the cord. The calculations in question seem to show that the shortening of the rocks due to folding in a line passing from the Allegheny Front northward through Punxsutawney was much smaller than would have been anticipated—not over 30 feet. Further south where the folding is more intense it would be much more. Time does not permit the following of the subject further at this time as the whole subject of the mechanics of mountain-making soon becomes involved.

“Another question is raised by observing these nodal lines and lines of maximum folding. Have there been axes of cross-folding action? This too will be passed at this time. It is probable that the completion of the structure of Somerset county and of the breaks existing within the area already enclosed will be necessary before some of these questions can be examined with any satisfaction.”

Horizontal Sections. In addition to the delineation of structure by contour lines, so well described by Dr. Ashley, it has been thought wise to accompany this map with a number of sections. These sections are constructed on a horizontal scale of 1-62,500 of Nature, 4 times that of the general map. The vertical scale of these sections is 1-12,000 of Nature. It will be noted that the horizontal scale is that of the published topographic maps, and therefore the relations of the geology to the surface structure can be readily determined by comparing these detailed sections with the topographic maps.

There are 7 of these detailed sections.

(1) A section extending from a point on the southern line on the Uniontown quadrangle, latitude $39^{\circ} 45'$, longitude $79^{\circ} 35'$, extending northward across the Uniontown and Connells-ville quadrangles to latitude $40^{\circ} 15'$. Thence eastward $10'$ to longitude $79^{\circ} 25'$, a point on the southern side of the Latrobe

quadrangle. From this point the section extends due north across the Latrobe, Elders Ridge, Rural Valley, and Clarion quadrangles, to the northern edge of the map in latitude $41^{\circ} 15'$, longitude $79^{\circ} 25'$.

(2) A section parallel to the preceding extending from a point on the southern line of the Rogersville quadrangle in latitude $39^{\circ} 45'$, longitude $80^{\circ} 25'$, extending due north across the Rogersville, Claysville, Burgettstown and Beaver quadrangles, to latitude $40^{\circ} 45'$.

(3) A section extending from a point on the eastern line of the Uniontown quadrangle, latitude $39^{\circ} 50'$, longitude $79^{\circ} 30'$, and extending due west across the Uniontown, Masontown, Waynesburg, and Rogersville quadrangles to longitude $80^{\circ} 30'$.

(4) A section extending from the eastern line of the Connellsville quadrangle, latitude $40^{\circ} 10'$, longitude $79^{\circ} 30'$, and extending due west across the Connellsville, Brownsville, Amity and Claysville quadrangles to longitude $80^{\circ} 30'$.

(5) A section extending from the northeast corner of the Indiana quadrangle, longitude $79^{\circ} 00'$, latitude $40^{\circ} 45'$, and extending thence due west along the northern line of the Indiana, Elders Ridge, Freeport, New Kensington, Sewickley and Beaver quadrangles to longitude $80^{\circ} 30'$.

(6) A section beginning at the southeast corner of the Uniontown quadrangle, longitude $79^{\circ} 30'$, latitude $39^{\circ} 45'$, and extending thence northwesterly across the Uniontown, Brownsville, Carnegie and Beaver quadrangles to longitude $80^{\circ} 30'$, latitude $40^{\circ} 45'$.

(7) A section extending from the southwest corner of the Masontown quadrangle, longitude $80^{\circ} 00'$, latitude $39^{\circ} 45'$, and extending thence northeasterly across the Masontown, Connellsville, Latrobe and Indiana quadrangles to longitude $79^{\circ} 00'$, latitude $40^{\circ} 45'$.

It is believed that these detailed sections will be of very great value to all students of the geology of the region.

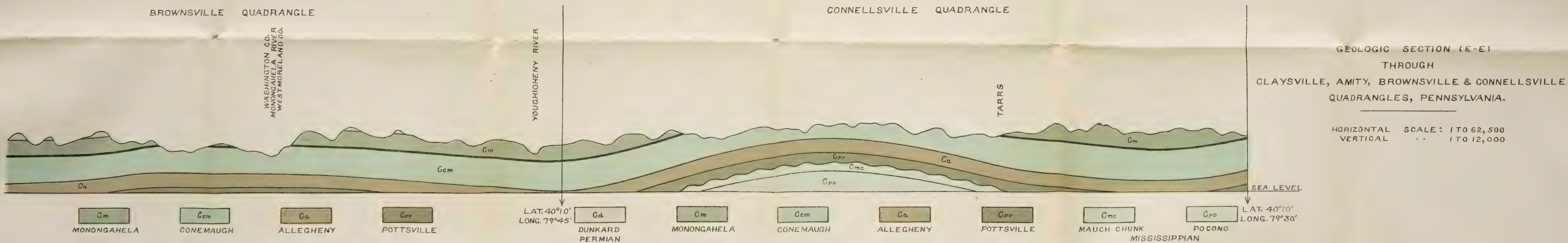
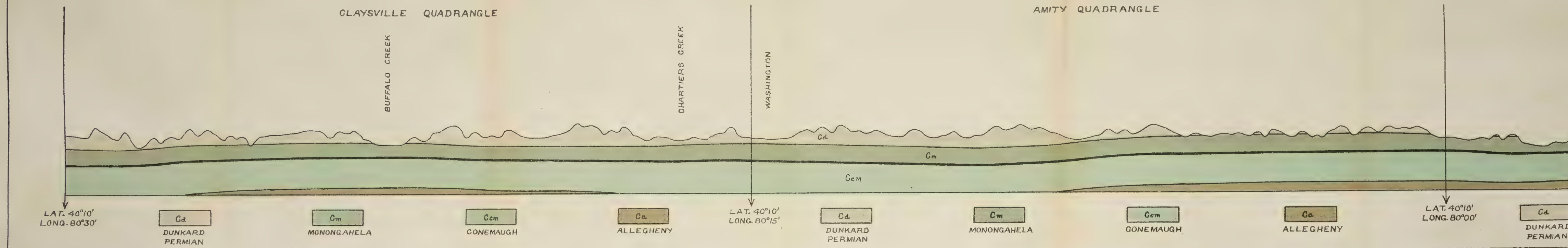
The importance of structure in connection with the accumulation into paying quantities of petroleum and natural gas cannot be over-estimated, and the direction and character of the various anticlinal and synclinal axes shown on the structure map, and by the detailed sections, cannot but be of interest

in this connection. It is realized, of course, that the structure as laid down on the horizon of the Pittsburgh coal does not entirely coincide with the structure on the producing sands found hundreds of feet beneath it. This difference in the structure of the deeper sands is not only due to local variations in the thickness of the intervening formations, but is a necessary result of the nonconformity at the base of the Pottsville before referred to. Owing, however, to the want of continuity in the oil sands over the portion of southwestern Pennsylvania embraced by the map, it is not practicable to depict the structure at the horizon of any one sand over so large an area. The relation and connection of the various oil and gas fields and pools to the structure is, however, very striking, as will be brought out in a map on which work is now in progress.

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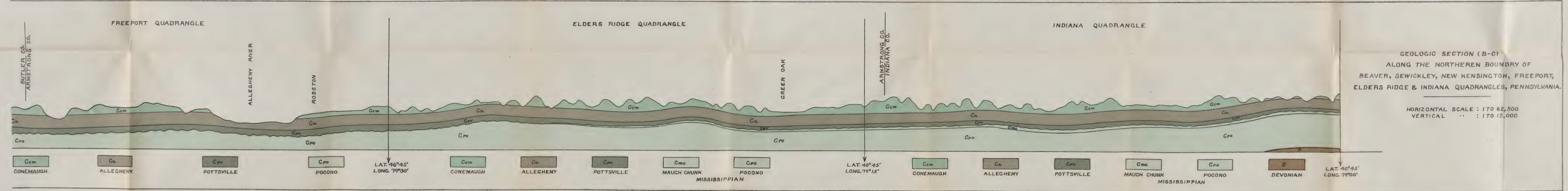
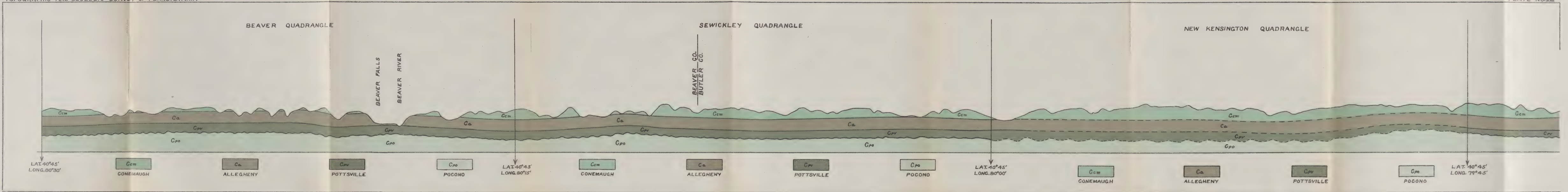
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GEOLOGIC SECTION (E-E)
THROUGH
CLAYSVILLE, AMITY, BROWNSVILLE & CONNELLSVILLE
QUADRANGLES, PENNSYLVANIA.

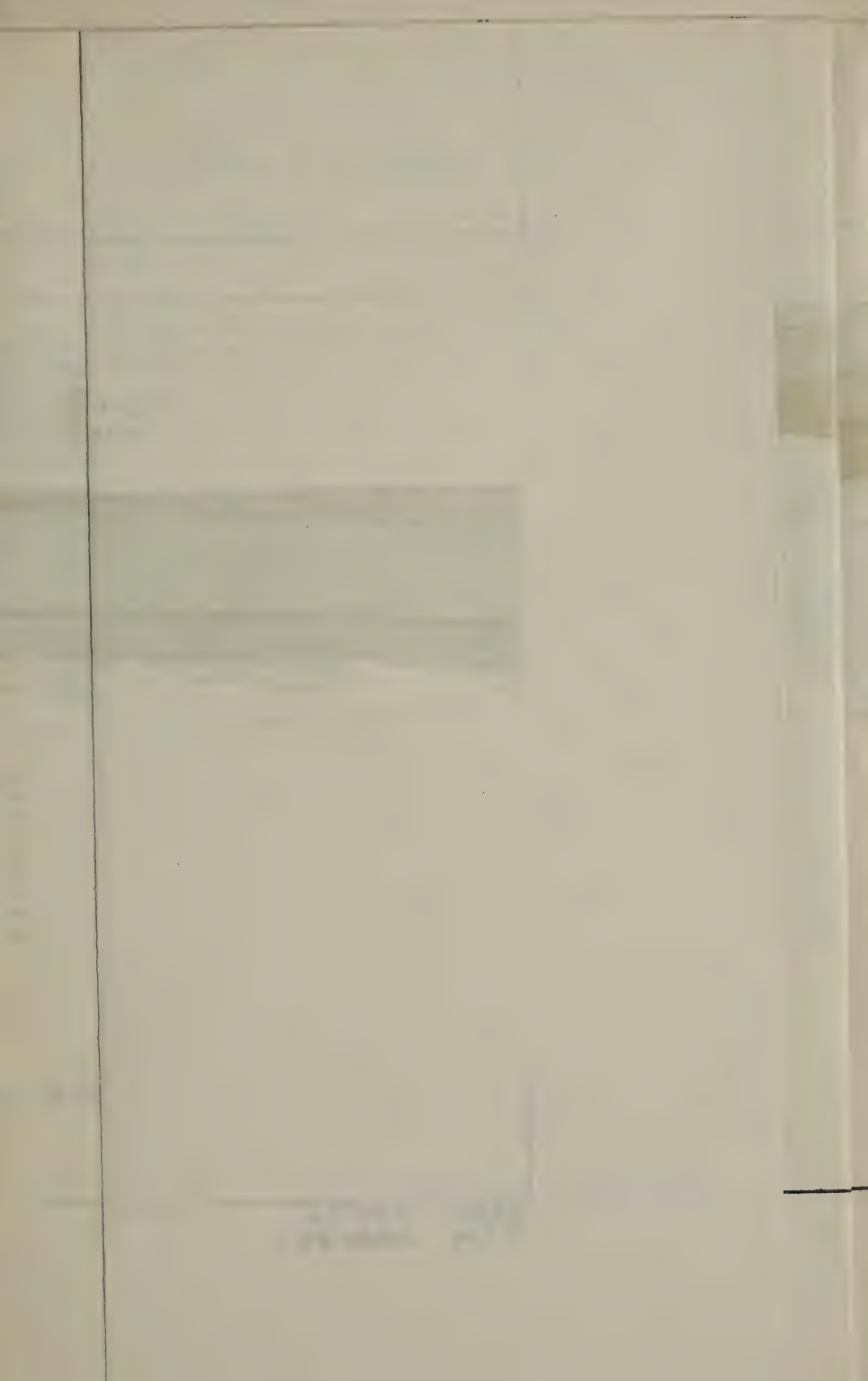
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VERTICAL " " 1 TO 12,000

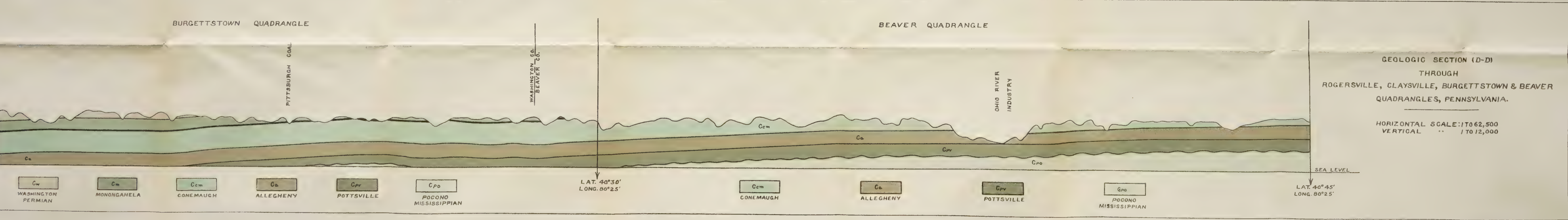
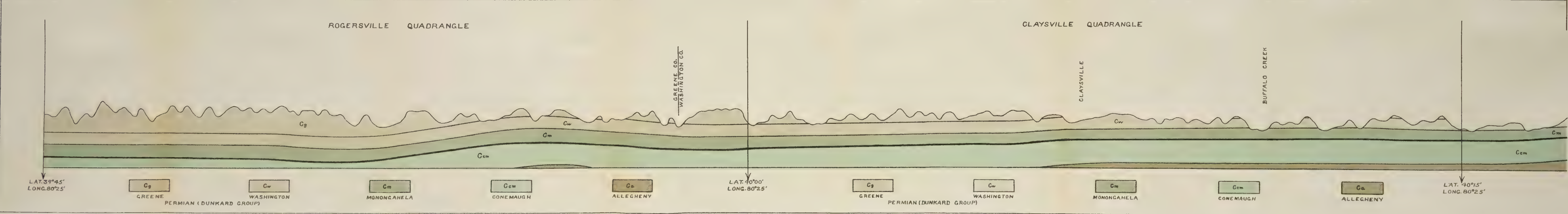
REPORT NO. 2
PLATE NO. VIII

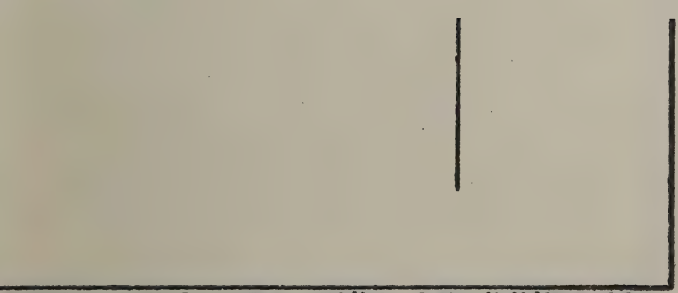


GEOLOGIC SECTION (B-C)
ALONG THE NORTHERN BOUNDARY OF
BEAVER, SEWICKLEY, NEW KENSINGTON, FREEPORT,
ELDERS RIDGE & INDIANA QUADRANGLES, PENNSYLVANIA.

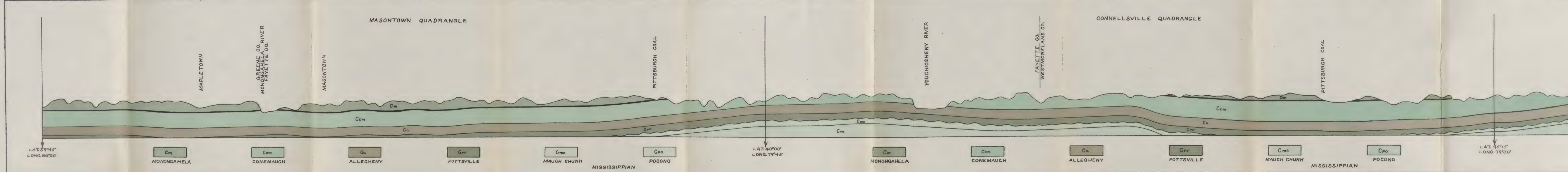
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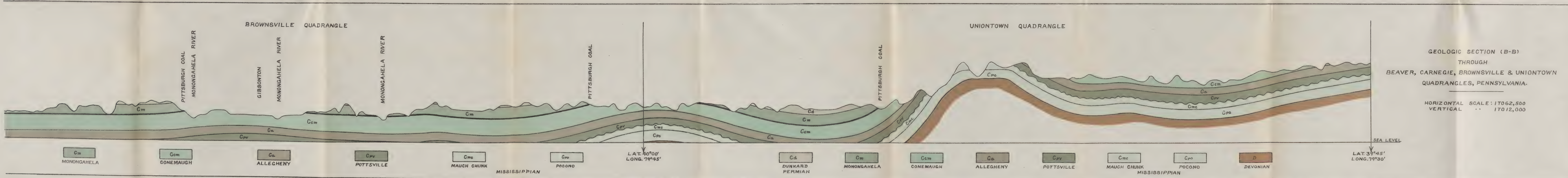
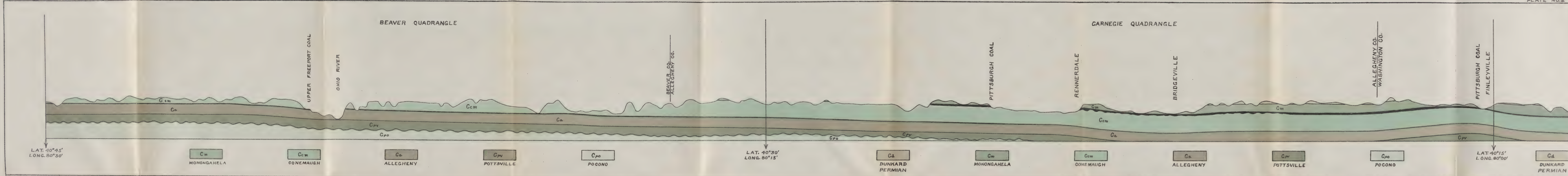


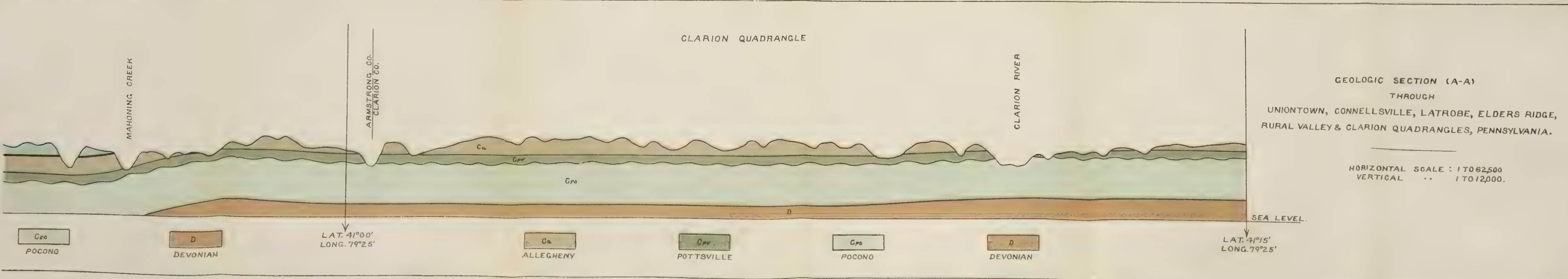
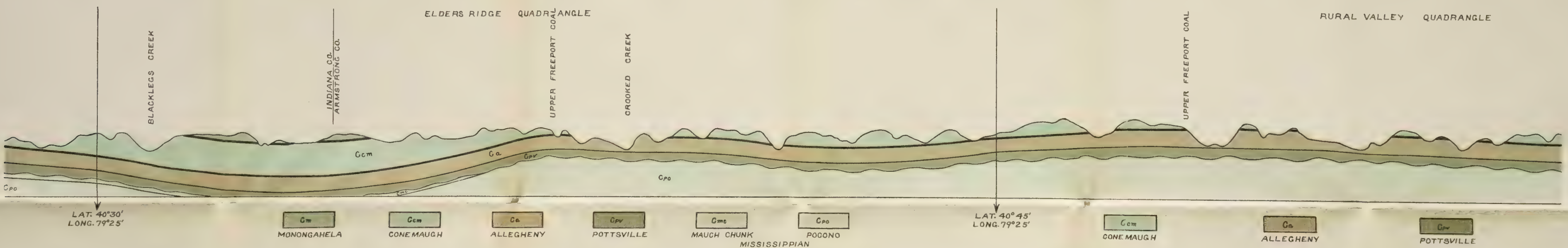
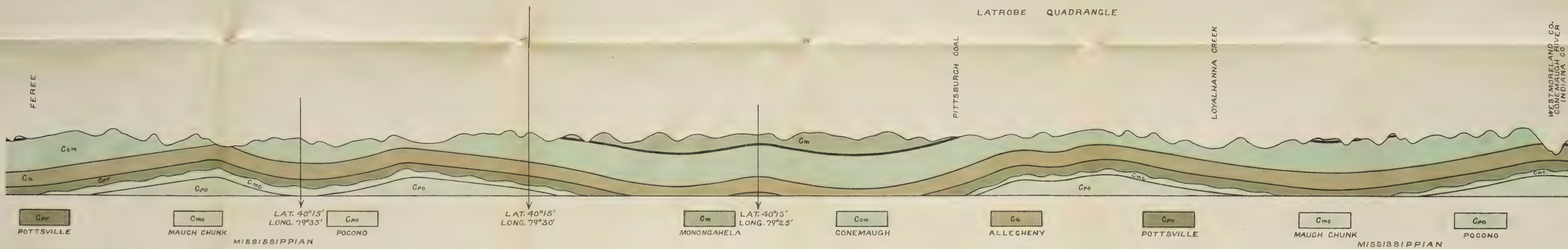
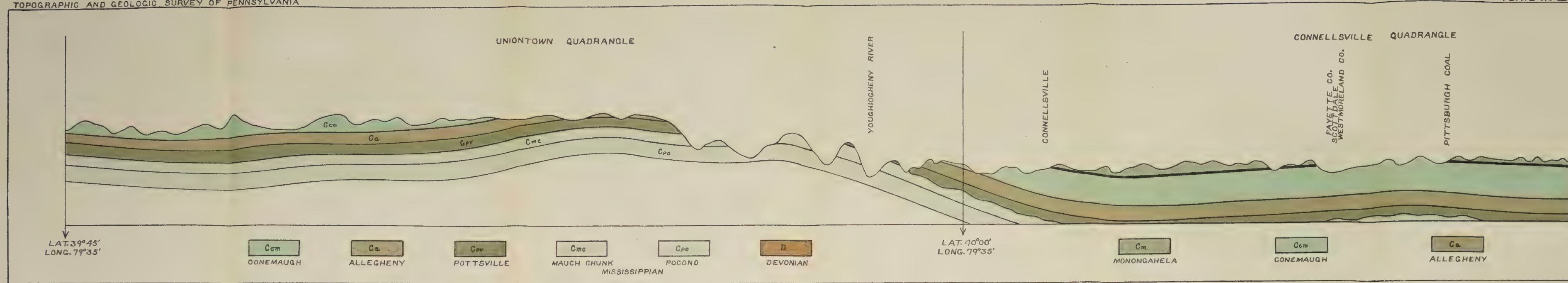


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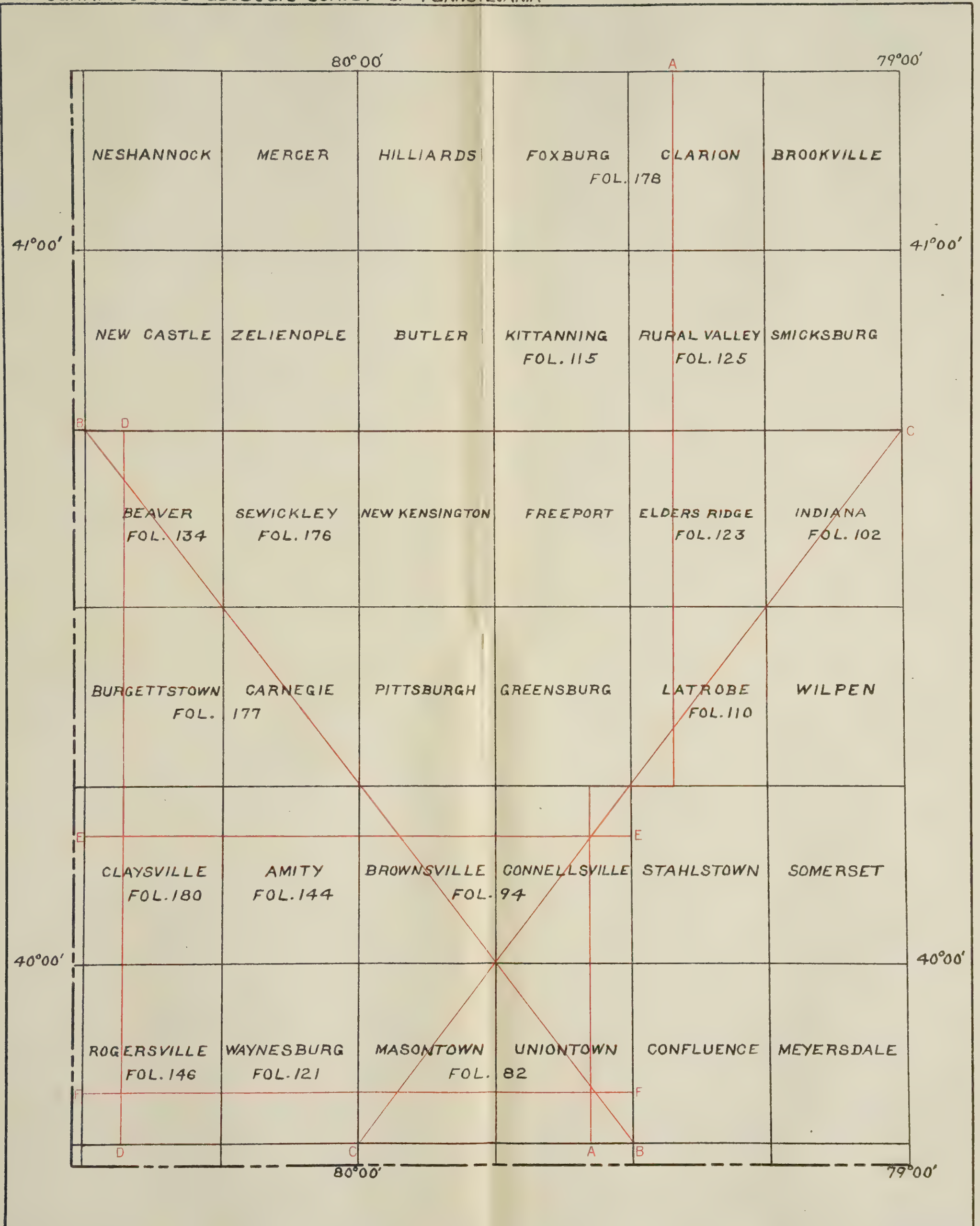




GEOLOGIC SECTION (A-A)
THROUGH
UNIONTOWN, CONNELLSVILLE, LATROBE, ELDERS RIDGE,
RURAL VALLEY & CLARION QUADRANGLES, PENNSYLVANIA.

HORIZONTAL SCALE : 1 TO 62,500
VERTICAL .. 1 TO 12,000.

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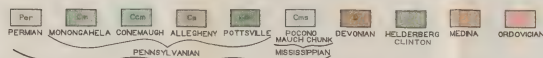


INDEX MAP SHOWING LOCATION OF HORIZONTAL SECTIONS



STRUCTURAL GEOLOGY OF SOUTHWESTERN PENNSYLVANIA STRUCTURE ON HORIZON OF PITTSBURGH COAL

LEGEND



CARBONIFEROUS

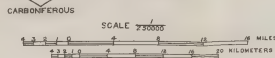
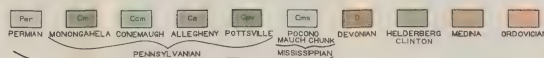
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AREAL GEOLOGY OF SOUTHWESTERN PENNSYLVANIA

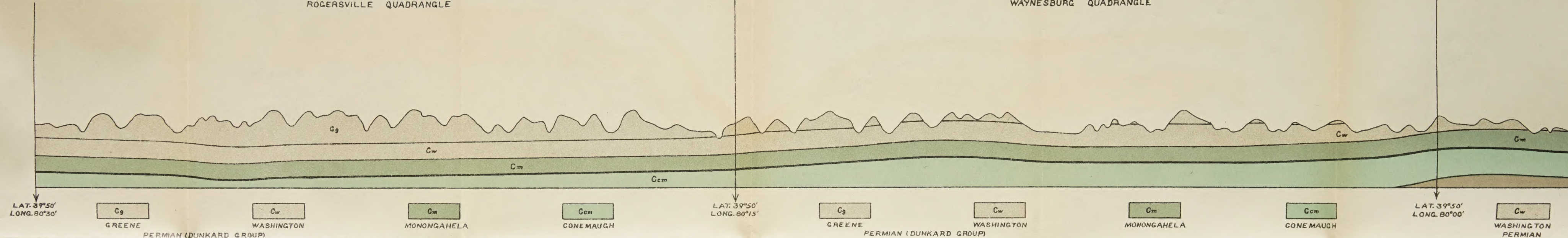
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WAYNESBURG QUADRANGLE



MASONTOWN QUADRANGLE

UNIONTOWN QUADRANGLE

